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(71) Applicant: **YAMAHA HATSUDOKI KABUSHIKI KAISHA**
2500 Shingai
Iwata-shi Shizuoka-ken, 438(JP)

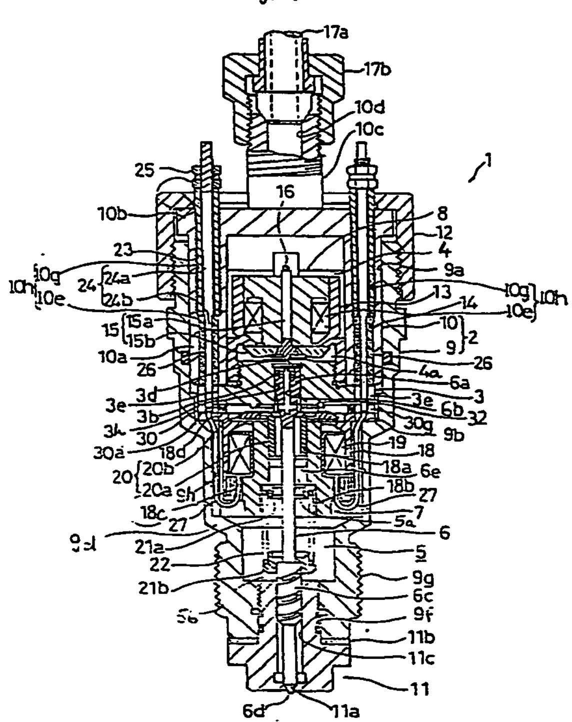
(72) Inventor: **Yoshida, Takeo**
3643-27 Nishikaizuka
Iwata-shi, Shizuoka-ken(JP)
Inventor: **Suzuki, Minoru**
2143-1 Shingai
Iwata-shi, Shizuoka-ken(JP)

(74) Representative: **Patentanwälte Grünecker, Kinkeldey, Stockmair & Partner**
Maximilianstrasse 58
W-8000 München 22(DE)

(54) High pressure fuel injection unit.

(57) The present invention relates to a high pressure fuel injection unit comprising a housing with a fuel injection timing control valve and a lift regulating solenoid actuator adapted to adjust the amount of fuel injected during a fuel injection cycle by means of a lift regulating member which is provided to engage a stopper portion of an injection valve body and, moreover, is adapted to selectively assume a predetermined lift regulating position in response to a lift regulating solenoid actuator being energized in advance of the fuel injection timing.

Fig. 1



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HIGH PRESSURE FUEL INJECTION UNIT

The present invention relates to a high pressure fuel injection unit comprising a housing whose inner space is partitioned into a fuel injection timing control chamber, accommodating a fuel injection timing control valve, and a pressurized fuel storage chamber which is communicated to a fuel injection nozzle co-operating with an injection valve body, operated by said fuel injection timing control valve, wherein the fuel injection timing control chamber and the pressurised fuel storage chamber are partitioned by a partitioning wall member which, in turn, defines a back pressure chamber which, on the one hand is fluidly communicated to a rear end portion of the injection valve body slidably supported by said partioning wall member and, on the other hand, is fluidly communicated to a back pressure relief chamber via an orifice passageway under control of said fuel injection timing control valve to fluidly connect the back pressure chamber to the back pressure relief chamber in response to the position of the injection valve body. Moreover, it relates to a control method for such a unit.

Thus, specifically the invention relates to a high pressure fuel injection unit which is suitable for a high speed diesel engine, for example. Specifically the present invention aims to improve the inherent structure of such an injection unit with respect to the fuel injection characteristics and the durability of electromagnetic control components thereof.

A high pressure fuel injection unit as indicated above (being of a so-called reservoir or accumulator type), particularly suited to be used for high speed diesel engines as well-known in the art (Japanese Patent Application No. Hei 1-36971).

Such a fuel injection unit of the fuel storage or accumulator type has a structure comprising a generally tubular housing, the internal diameter of which reduces stepwise from a top portion to a lower attachment portion at the side of the fuel injection nozzle. Said housing is partitioned into an accumulator or fuel storage chamber at a lower portion thereof adjacent to the fuel injection nozzle and an injection timing control chamber at an upper portion of the housing, both chambers being separated by means of a partitioning wall member which forms a guide structure as well and defines a back pressure chamber to which a rear end of an injection valve body of the fuel injection valve is exposed. Said rear end portion of the injection valve body, the tip end of which co-operates with the fuel injection nozzle to form the fuel injection valve, is slidably supported by said partitioning wall member and is prebiased into a closed position of the injection valve by a prebiasing spring assisted by he fuel back pressure applied to the rear end portion of the injection valve body. On the other hand, the injection valve body is subjected to the fuel pressure acting thereon in an opposite direction biasing the injection valve body in an open position of the fuel injection valve. A fuel back pressure of the pressurised fuel, thus, forms a governor pressure which is regulated by a fuel injection timing solenoid disposed in the upper portion of the housing through of a valve member provided to perform a relief control of an orifice passageway communicating said back pressure chamber to a back pressure relief chamber disposed at the upper injection timing control chamber side of the partitioning wall member.

With the afore-indicated fuel injection unit of a fuel storage type, a back pressure acts on the rear end face of the injection valve body of the fuel injection valve when the orifice passageway is closed by the valve member of the injection timing control valve formed by an injection timing solenoid actuator. Accordingly, the injection valve body is advanced by the resultant of the back pressure, fuel pressure and downwardly prebiasing force keeping the injection valve body in a lowered position closing the injection nozzle. When, on the other hand, the back pressure prevailing in the back pressure chamber is released by a retracting operation of the valve member of the injection timing control valve to open the orifice passageway, the injection valve body is lifted by the fuel pressure acting against the prebiasing force of the prebiasing spring element to overcome said prebiasing force urging the injection valve member into a retracted valve position, thus opening the injection valve nozzle. Normally, the maximal stroke or lift amount of the injection valve body depends on the axial play of the rear end portion of the valve body with respect to an opposite abutment face of the back pressure chamber defined by the partitioning wall member.

Taking the afore-indicated structure of such a fuel injection unit into consideration there is a need to closely approach to different needs of fuel injection depending on the operational conditions of the engine and, therefore, a more elaborated control of the amount of fuel injected through such an injection unit is reccommendable. Moreover, in providing an elaborated control for the amount of fuel injected per injection cycle, care should be taken to avoid a thermical or other overload to arise for the solenoid control means of the injection valve unit. Finally, it is an objective of the present invention to improve the control of such a high pressure fuel injection unit.

The present invention aims to meet the afore-

indicated objectives by means of a high pressure fuel injection unit which, according to the present invention, is characterized in that a lift regulating member is provided to engage a stopper portion of the injection valve body and, moreover, is adapted to selectively assume a predetermined lift regulating position in response to the energization of a regulator means which is energized to set the lift regulating member to said predetermined lift regulating position prior to a fuel injection timing, i.e. in advance of the injection valve being opened retracting the injection valve body into an open positioned spaced from the injection nozzle.

With respect to a control method for a high pressure fuel injection unit, specifically of a type as indicated above, the present invention sets forth a method wherein a lift regulator means for the injection valve body, is energized prior to the actuator means for retracting the injection valve body. Preferably, the movement of a lift regulating member to a lift regulating position is completely terminated prior to the injection valve pin being actuated in a retracted position opening a fuel injection nozzle.

In Japanese Patent Application S63-259563 the applicant of the present application has already proposed a regulating structure by means of which the stroke or lift amount of the injection valve body can be changed in two steps providing a large or small degree of injection valve opening. Said structure employs a lift regulating member to adjust the stroke of the valve body to a smaller lift, allowing a stopper portion formed on the injection valve body to abut against the lift regulating member, wherein the lift regulating member in turn is adjusted by means of the attraction pull of a lift electromagnetic solenoid energized to move the lift regulating member in its lift regulating position. However, when the lift regulating member is controlled by an electromagnetic coil to assume its lift regulating position to restrict the retractive opening movement of the injection valve body the coil of the electromagnetic lift solenoid is energized continuously to attract and hold the lift regulating member in its attracted regulating position.

In that case it is required to hold the lift regulating member during the entire period of small lift operation of the injection valve body in its lift regulating position with such a force larger than the force driving the injection valve body in its opening direction. Thus, continuously applying the attraction pull to the valve regulating member to keep it in its valve regulating position requires supplying the electromagnetic coil of the lift electromagnetic solenoid with a relatively big electric current for a longer period inducing the risk that the electromagnetic coil of the lift solenoid suffers from overheating so that the coil may be damaged by burning.

The high pressure injection unit according to the present invention is specifically advantageous in that, on the one hand, it enables to regulate the opening degree of the injection valve to be varied to alter the amount of fuel injected during a fuel injection cycle in response to the operating conditions of the engine, but on the other hand, reliably prevents the electromagnetic control means of the regulating member for adjusting the lift of the injection valve body to be overheated by the hold current fed through the electromagnetic coil of the attraction pull generating solenoid. The latter effect specifically results from the inventive timing control for exciting the electromagnetic coil of the lift electromagnetic solenoid, namely to start energization of the electromagnetic coil of the lift regulating solenoid actuator for attracting the valve regulating member into a valve regulating position prior to the start of the fuel inejction, i.e. prior to the electromagnetic coil if the injection timing solenoid actuator being excited to attract the associated valve member of the back pressure relief control means of the injection unit. Specifically as the electromagnetic coil of the lift regulating solenoid is excited at such a timing that preferably the attracting movement of the lift regulating member to its lift regulating position is completed prior to the electromagnetic coil of the injection timing sol noid being excited (start of fuel injection) a low current electromagnetic coil having slower start-up characteristics can be employed for the lift regulating solenoid. According it is possible to reduce the electric current fed through the lift regulating solenoid by increasing the number of turns of the coil. Consequently, supplying a big electric hold current producing a large attracting pull for a long period is dispensable enabling the occurence of a burning damage of the lift electromagnetic coil of the lift regulating solenoid to be reliably prevented improving the durability thereof.

According to a preferred embodiment of the present invention the fuel injection timing of the injection unit is adapted to be controlled by an injection timing solenoid actuator adapted to perform a pressure relief control of a back pressure acting upon the rear end face of the injection valve body to allow a fuel pressure operated movement of the injection valve body for opening or closing the associated fuel injection nozzle of the injection valve.

Moreover it is preferred that the lift amount of the injection valve body of the fuel injection valve is controlled by a lift regulating solenoid actuator which is disposed inside the pressurized fuel storage chamber and it adapted to dispose the lift regulating member at a predetermined lift regulating position determining the retraction (lift) of the injection valve body during a fuel injection cycle of

the unit.

Other preferred embodiments of the present invention are laid down in the other sub-claims.

Further features, objectives and advantages of the present invention will become more apparent from the following description of preferred embodiment of the present invention in conjunction with the accompanying drawings wherein;

Figure 1 is a sectional front view of the high pressure fuel injection unit according to an embodiment of the present invention,

Figure 2 is a sectional side view of the high pressure fuel injection unit as shown in Fig. 1,

Figure 3 is a wave form diagram for explaining a control of the high pressure fuel injection unit as shown in Fig. 1,

Figure 4 is a sectional view of a back pressure chamber area of the high pressure fuel injection unit of Fig. 1, shown in a larger scale,

Figure 5(a) is a bottom view of a shim member associated to a rear end portion of an injection valve body of the high pressure fuel injection unit as shown in Fig. 1,

Figure 5(b) is a sectional view according to Fig. 5(a),

Figure 6 is a sectional view of a control portion of the high pressure fuel injection unit of Fig. 1 showing the area of an upper portion of the valve regulating member in larger scale, and

Figure 7(a) and Figure 7(b) is a side view and a bottom view, respectively of a stopper plate as shown in Fig. 6 adapted to cooperate with the lift regulating member to determine a maximum lift of an injection valve body of the high pressure fuel injection unit as shown in Fig. 1.

In Figs. 1 and 2 and 3 to 7 the reference numeral 1 generally denotes a high pressure fuel injection unit according to this embodiment of the present invention which, in its basic structure, comprises a housing 2 partitioned into an upper fuel injection timing control chamber 4 and a lower pressure fuel storage chamber 5 (wherein the pressurized fuel is accumulated) by means of a partitioning wall member 3 disposing an injection valve body 6. Within the fuel storage chamber 5 a lift regulating solenoid actuator 7 for regulating the amount of the lift of the injection valve body 6 is disposed while an axial projection 3a of the partitioning wall member 3 is adapted to support an injection timing solenoid actuator 8 (hereinafter referring to as injection timing control valve 8) disposed in the fuel injection timing control chamber 4 and adapted to control the timing of fuel injection by controlling the resultant force urging the injection valve body 6 in its injection valve closing position, as explained in full detail as description proceeds. Generally the housing 2 is composed of a tubular main body 9 and a cover insert 10 for closing the insert opening 9a of the main body 9. The tubular main body 9 has a generally cylindrical shape with its diameter reducing in three steps from a top portion thereof to the lower injection nozzle side portion of the injection 1. The size of the injection timing control chamber 4 is substantially determined by the diameter of the insert opening 9a at the upper portion of the fuel injection unit 1, whereas a step portion or shoulder 9b projects inwardly at approximately half the axial extension of the fuel injection unit nd is adapted to hold a plurality of members accommodated in said main body 9 as described hereinafter. Another accommodation opening 9h is formed to extend downwardly from the shoulder 9b, thus defining an upper part 5a of the pressurized fuel storage chamber 5 accommodating the lift regulating solenoid actuator 7 (hereinafter referred to as lift solenoid 7) and terminating into a lower part 5b of the fuel storage chamber 5 with a step 9d in betwen both parts 5a and 5b of the fuel chamber storage chamber 5. A fuel injection nozzle cap 11 is screwed from below into a holding opening 9f of the lower extension of the main body 9 of the injection unit 1 and, moreover, provided to complete the lower wall of the fuel storage chamber 5. Along an axis portion of the nozzle cap 11 a guide hole 11c for guiding the slide section 6c of the injection valve body 6 is provided, the tip end portion of the guide hole 11c constitutes the fuel injection nozzle 11a. A selectively applicable intermediate shim 11b is provided to adjust a minimal amount of the lift of the injection valve body 6 whereas reference numeral 9g denotes a mounting screw portion for fastening the complete high pressure fuel injection 1 on the engine, for example a high speed diesel engine.

The afore-mentioned cover insert 10 has the shape of a flanged hollow cylindrical member integrally established from a cylindrical tube portion 10a and a top plate portion 10b, said cover insert 10 is adapted to accommodate the injection timing control valve 8 and to form a fastening and guide member for other elements. The top plate portion 10b is provided with a connecting pipe portion 10c projecting upwardly through an upper closing cap 12, said connecting pipe portion 10c is adapted to fasten a fuel supply tube 17a through a connector nut 17b. A fuel passage 10b extends axially through the connector portion 10c and through a portion of the cover insert 10, specifically through the cylindrical tube portion 10a (see Fig. 2) and through a flange portion of the partitioning wall member 3 to terminate into a back pressure chamber 4a as described later on.

The cylindrical tubular portion 10a of the cover insert 10 is inserted into the insert opening 9a of the main body 9 and the top plate portion 10b of the cover insert 10 is pressed down by the closure

cap 12 screwed and mounted onto the upper end portion of the main body 9 of the housing 2. Accordingly, a peripheral portion of the partitioning wall member 3 and a radially projecting upper rim portion of a coil holder 18 of the lift solenoid 7 are pressed against and fixed on the step portion 9b by a lower end portion of the tubular portion 10a of the cover insert 10, as shown in Figs. 1 and 2. Reference numeral 30 denotes a spacer disposed in between a circumferential rim portion of the partitioning wall member 3 and the coil holder 18.

The above injection timing control valve 8 comprises a bisectional coil holder 13 screwed and mounted on the central projection 3a of the partioning wall member 3, a ring shaped electromagnetic coil 14, supported within the coil holder 13 and an axial movable valve body 15, comprising a valve stem 15a slidably inserted through a coaxial hole of the coil holder 13 and a disk shaped abutment portion 15b as shown in greater detail in Fig. 4. A feeder terminal 31 (Fig. 2) is disposed and supported through the top plate portion 10b of the cover insert 10 to electrically connect the ring coil 14 to an external power source.

An upper end of the valve stem 15a is in engagement with a pushing spring 16 urging the valve member 15 into a downwardly advanced valve closing position as described later on. Accordingly, an orifice passageway 3d of a back pressure chamber 3b is usually kept closed by a central valve protrusion 15c formed at the lower end of the valve stem 15a and said orifice passageway 3d is adapted to be opened by attracting the disk-shaped atubment portion 15b fixed on the valve stem 15a by means of the electromagnetic coil 14.

On the other hand the electromagnetic lift solenoid 7 disposed downstream of the partitioning wall member 3 in the upper part 5a of the fuel storage chamber 5 comprises a bisectional coil holder 18, a ring shaped electromagnetic coil 19 supported within the coil holder 18 and a lift regulating member 20 for regulating the amount of the lift of the injection valve body 6, specifically delimiting the lift of the injection valve body to a smaller value (smaller amount of fuel injection) when the lift regulating member 20 assumes it lift regulating position. The upper peripheral rim portion of the coil holder 18 is pressed against and fixed on the step portion 9b of the main body 9 of the housing 2 through the tubular portion 10a of the cover inset 10 as indicated above. The lift regulating member 20, as to a certain extent also shown in figure 6, comprises a tubular guide portion 20a slidably inserted into a guide hole 18a of the coil holder 18 and a disk-shaped abutment portion 20b fixed on the upper end of the cylindrical guide portion 20a. As is shown in greater detail in Fig. 6 the upper end face of the coil holder 18 comprises a stepped portion 18f projecting up around its axis. Said stepped portion 18f is adapted to establish a magnetic circuit interrupting portion by means of a gap A in between an outer ring portion of the backside of the disk shaped abutment portion 20b and the adjacent facing portion of the upper end surface of the coil holder 18 on the occassion that the disk shaped abutment portion 20b is attracted downwardly to adhere at the upper end face of the coil holder 18 improving the response characteristics of said lift regulating member 20 to be freely axially movable upon switching off of the energizing current supplied through the coil 19 of the lift solenoid 7. Thus, said gap A assists in abruptly reducing the magnetic attraction force when the energization of the electromagnetic coil 19 is switched off. Moreover said gap A weakens the magnetic circuit and enables the lift regulating member 20 to quickly assume its freely movable condition upon interruption of driving an electrical current through the coil 19.

Generally the lift electromagnetic coil 19 of the lift solenoid 7 is of a small current type formed by winding a wire having a small diameter by a large number of turns and, accordingly the start-up of the magnetic force and the movement of the lift regulating member 20 is relatively slow as is also explained with respect to Fig. 3 later on.

In contrast hereto, the characteristics of the electromagnetic coil 14 of the upper injection timing control valve 8 is of a big current type formed by winding a wire having a larger diameter by a smaller number of turns, thus employing a big current type coil having quick starts-up of the magnetic force and of the valve member 15 as indicated in Fig. 3 as well. For example, the injection electromagnetic coil 14 is of the type A > T in terms of its ampere turn characteristics. In this way it is possible to improve the control accuracy of the injection timing by rendering the start-up characteristics of the magnetic force curve as steep and quick as possible driving a large current through the coil 8. On the other hand as indicated above, the electromagnetic lift coil 19 of the lift solenoid 7 employs a coil of the type formed of electric wire having a smaller diameter wound by a large number of turns that is the coil 19 is of the type A < T in terms of its ampere turn characteristics. Such a design is selected as a slow start-up characteristic is sufficient for the lift electromagnetic coil 19 and the operation of the lift regulating member 20 of the lift solenoid 7 as there is a sufficient time available for energizing and attracting the lift regulating member 20 in its attracted lift regulating position.

Reference numeral 32 denotes an annular stopper plate made of non magnetic material which

is fixed on the lower surface of the partitioning wall member 3 in a coaxial manner as shown in Fig. 6. As is shown in Fig. 7 said stopper plate 32 is provided with grooves 32a recessed in its contact surface 32b facing the upper side of the disk shaped abutment portion 20b of the lift regulating member 20. Said grooves 32a are formed crosswise serving to introduce the pressurized fuel from the fuel supply passage 3e of the partioning wall member 3 to the guide portion 20a of the lift regulating member 20 receiving a portion of the injection valve body 6 therethrough. The stopper plate 32 forms a magnetic shield serving to prevent a magnetic circuit from being produced through the partitioning wall member 3 under the condition that the lift regulator member 20 is in its unbiased raised position and the lift solenoid 7 is energized to attract the lift regulating member 20. Moreover, by exchanging the stopper plate 32 to another one having a different thickness it is also possible to modify the raised position of the lift amount of regulating member 20 and, accordingly, to adjust the maximum amount of the lift of the injection valve body 6.

Morover, the cylindrical tube portion 10a of the cover insert 10 comprises a pair of knock pin holes 10f at the leading end thereof with knock pins 29 fitted therein to engage knock pin holes 9e at the step portion 9b and extending through knock pin grooves 3g, 30c and 29e formed to penetrate the peripheries of the partitioning wall member 3, the spacer 30 and the coil holder 18, respectively.

In order to supply energy to the coil 19 of the lower lift solenoid 7 wiring passages are formed through the high pressure fuel injection unit 1 substantially extending in an axial direction thereof from the top of the fuel injection unit extending axially through the closure cap 12 and the cylindrical tube portion 10a of the cover insert 10 to connect to the lift electromagnetic coil 19 from below. Such a structure is preferred and particularly advantageous in order to avoid a space-consuming radially extending wiring harness for feeding the lower electromagnetic coil 19, thus increasing the installation freedom and assuring a high sealability of the pressurized fuel storage chamber 5. Specifically, the wiring passages for feeder wires connected to the coil 19 of the lift solenoid 7 are constituted by guide holes 18c of a portion of the coil holder 18 beneath the lower end of the electromagnetic coil 19, guide grooves 9h, 18d, 30a and 3c along a portion of the housing's main body 9 surrounding the lift solenoid 7, the coil holer 18 and the spacer 30 as well as of the peripheral portion of the partitioning wall member 3 terminating into take out holes 10h of the cylindrical tubular portion 10a of the cover insert 10 through the top plate portion 10b thereof to the outside at the top portion of the high pressure fuel injection unit 1. The take out hole 10h respectively, comprises a holding portion 10g formed by its upper half, and a sealing portion 10e formed by its lower half forming a receipt structure for an insulating pipe 23 made of insulating material which is screwed into the holding portion 10g respectively and is fixed therein with an adhesive. The insulating pipe 23 is adapted to receive a feeder rod 24 which is, for example, a rod made of copper inserted into the insulating pipe 23 and constituting a part of a feeder wire. Said conductive rod is fixed to the inner surface of the insulating pipe 23 with an adhesive and its upper end portion axially projecting out of the housing 2 is fixed by a lock nut 25. A soft sealing adhesive 24 is filled in between a portion 24b of the feeder rod 24 having a smaller diameter and the sealing portion 10e of the take out hole 10h. The lower end of the portion 24b of the feeder rod 24 is positioned near to the guide groove 30a of the spacer 30. The wire harness 27 which is drawn out from both ends of the winding of the electromagnetic coil 19 is fed through the guide hole 18c and the guide groove 9h to the vicinity of the spacer 30 to be connected at that position through soldering with the lower end of the thinner portion 24b of the feeder rod 24.

The partitioning wall member 3 including the threaded protection 3a is generally disk shaped having a guide hole 3h formed at its center portion into which a rear end portion 6a of the upper end of larger diameter of the injection valve body 6 if slidably inserted. As shown in Fig. 4, this space confined ahead of the rear end portion 6a of the injection valve body 6 defined by the guide hole 3h of the partitioning wall member 3 and the upper rear end face 6h of the injection valve body 6 defines a back pressure chamber 3b which is communicated with a back pressure relief chamber 4a at the side of the injection timing control chamber 4 between the upper end of the protrusion 3a of the partioning wall member 3 and the disk shaped abutment portion 15b of the injection timing control valve 8, a circumferential wall of the back pressure relief chamber 4a being defined through the coil holder 13 of the injection timing control valve 8. Said communication in between the back pressure chamber 3b and the back pressure relief chamber 4a is established by means of an orifice passageway 3d, an opening thereof to the back pressure relief chamber 4a being controlled by means of a central protrusion 15c of the valve member 15 of the injection timing control valve as shown in Fig. 4 On the other hand, the back pressure chamber 3b with a back pressure herein acting on the upper rear end surface 6h of the rear end portion 6a of the injection valve body 6 is communicated to the fuel supply passageway and the fuel storage cham-

ber 5 through a throttle hole 6f and a communicating hole 6b both extending through the upper rear end portion 6a of the injection valve body 6 having an increased diameter. The peripheral portion of the partitioning wall member 3 includes a fuel groove 3e extending therethrough to be communicated to the fuel passage 10d connecting the fuel passage 10d of the cover insert 10 with the fuel storage chamber 5.

In order to assist an injection valve opening retracting force being applied to the injection valve body 6 through the static pressure of the pressurized fuel a transition range from a middle portion of the injection valve body 6 to the rear end portion 6a thereof having an increased diameter forms a cone portion 6g as shown in Fig. 4.

Morover, the injection valve body 6 is provided with a guide portion 6c formed at its lower portion and comprising a helical fuel supply groove and a tip end 6d formed at its lower end for opening or closing the associated injection nozzle 11a thus forming an injection valve. Moreover, a stopper portion 6e is formed at the middle part of the injection valve body 6 having a cross-shaped cross-section. The upper face of said stopper portion 6e is adapted to be disposed engageably opposite to the lower end face of the guide portion 20a of the shift regulating member 20. Accordingly the engagement position between the stopper portion 6e and the facing end of the guide portion 20a of the shift regulating member 20 determines the stroke of the injection valve body 6. An urging spring 22 is disposed between a lower spring seat 21b mounted on the guide portion 6c and an upper spring seat 21a inserted in a receipt section 18b formed at the lower portion of the guide hole 18a of the coil holder 18. By means of said urging spring 22 the injection valve body 6 is kept urged in the direction for closing the injection nozzle 11a. Finally as already mentioned above and shown in Fig. 4 on the upper rear end face 6h of the rear end portion 6a of the injection valve body 6, said portion 6a having an increased diameter, the lift amount adjusting shim plate 28 is disposed and the distance between the upper surface of said shim plate 28 and the opposite facing surface 3f of the back pressure chamber 3b constitutes the maximum amount of the lift of the injection valve body 6. As shown in Figs. 5a and 5b said shim plate 28 is an annular plate and its lower surface is provided with abuting faces 28a projected every 90° forming recessed portions 28b for introducing the fuel pressure to act upon the rear end face 6h of the rear end portion 6a of the injection valve body 6, said recessed portions 28b being constituted in between adjacent abutting faces 28a in circumferential direction of the shim plate 28. As shown in Fig. 4, preferably, said shim plate 28 can be installed upside down.

In the following the action and effects of the high pressure fuel injection unit according to the present invention will be explained mainly referring to Fig. 3.

In Fig. 3 wave form diagrams for explaining the operation of the high pressure fuel injection unit according to the present invention are shown.

With the fuel injection unit 1 according to this embodiment of the present invention the amount of fuel injection can be changed and selected in two steps by changing the amount of the lift of the injection valve body 6 either to a small lift 1 or a larger lift L as indicated in Fig. 3(i). In case the lift amount is regulated to the smaller one, firstly, the control signal for the lift solenoid 7 is supplied to the electromagnetic coil 19 (Fig. 3(e)), by which the driving current and the attracting magnetic force are generated (as shown in Fig. 3(f) and 3(g)), resulting in the lift regulating member 20 being attracted on the coil holder 18 of the lift solenoid 7 when the magnetic force reaches a predetermined magnitude, as shown in Fig. 3(h). As the electromagnetic lift coil 19 is of a small current type formed by winding a wire having a small diameter by a larger number of turns and accordingly, the start-ups of the magnetic force and the attracting movement of the lift regulating member 20 are slow, as shown in Fig. 3, the start-up timing of the above control signal is set in such a manner that the movement of the lift regulating member 20 can be completed prior to the fuel injection timing, taking the afore-indicated design aspect into consideration.

On the other hand, at the occurence of the injection timing the injection timing control signal is supplied (Fig. 3(a)) resulting in a large driving current being supplied to the electromagnetic coil 14 of the injection timing valve 8 and, accordingly, the magnetic attraction pull or force is abruptly generated and accordingly, the valve body 15 is attracted to abut against the lower surface of the coil holder 13 with a high speed as shown in Figs. 3b to 3d. The quick upwards movement of the valve body 15 results in a corresponding opening of the orifice passageway 3d accompanied by the fu l back pressure prevailing in the back pressure chamber 3b being released to the back pressure relief chamber 4a and, accordingly, the injection valve body 6 is correspondingly lifted through the action of the fuel pressure of the pressurized fuel which is set to overcome the prebiasing force of the urging spring 22 of the injection valve body 6. Thus, the injection valve body 6 lifts until the stopper portion 6e thereof abuts against the lower end face of the lift regulating member 20 held at a lift amount regulating position, that is attracted to the coil holder 18 by means of the energized lift

coil 19, and is lifted by the smaller lift amount. After having been once completely lifted it is then only necessary to keep the valve body 15 at its lifted attracted state and, accordingly, the driving current is immediately changed to a lower valve as shown in Fig. 3(b).

In case the larger lift L of the valve injection body 6 for injecting a larger amount of fuel is to be selected the level of the control signal to the lift solenoid 7 is set to be low (see Fig. 3(e)), the driving current is interrupted or switched off (Fig. 3-(f)) and the magnetic attracting force is reduced as shown in Fig. 3(g) causing a reduction of the attracting force acting on the lift regulating member 20 which, accordingly, is freely movable within the space available and, accordingly, the injection valve body 6 is lifted up to the larger lift amount L, carrying and pushing up the lift regulating member 20 as far as possible (Fig. 3(i)). After the expiration of the duration of fuel injection, the level of the control signal applied to the injection timing control valve 8 is said to be low (Fig. 3(a)), the magnetic force through the interruption or switching off of the driving current is reduced (see Fig. 3(b) and 3(c)) resulting in a downwards movement of the valve body 15 lowered by the pushing spring 16 to close the orifice passageway 3c by means of the projection 15c. Accordingly, further pressure release from the back pressure chamber 3b to the back pressure relief chamber 4a is prevented and against the back pressure is built up on the back pressure chamber 3b assisting the prebiasing force of the urging spring 22 to advance the injection valve body 6 in its closing position and the injection nozzle 11a is closed by the injection valve body 6 to terminate the fuel injection.

Accordingly, the timing of energization of the lift solenoid 7 according to the present invention is set to precede the timing of energization of the injection timing control valve 8 and, preferably, is set to be such that the movement of the lift regulating member 20 is completed prior to the injection timing. Thus, the damage of the electromagnetic coil 19 of the lift solenoid 7 caused by burning can reliably be prevented and the durability of the system can be improved. That means as the energization start timing has been shifted to an earlier timing an electromagnetic coil 19 having slow start-up characteristics can be employed as lift coil and therefore its characteristics can be chosen to be suitable for an electromagnetic coil performing lifting of the injection valve body 6, thus, creating a sufficiently large force for attracting the valve regulating member 20 without necessarily driving a large electric current through the coil 19 and, thereof, any burning damage accident with respect to that coil 19 can be prevented.

Moreover, as an air gap A is provided between the coil holder 18 of the lift solenoid 7 and the disk-shaped abutment portion 20b the magnetic attraction pull can be abruptly reduced when the electric driving current through the coil 19 is interrupted or switched off and, therefore the lift regulating member 20 can be freed at once enabling the injection valve body 6 to be rapidly switched over to a larger lift L contributing to improve the control acuracy of the fuel injection performed by the fuel injection unit 1 as a whole.

With respect to the electromagnetic coil 14 of the injection timing control valve 8 a need to produce a large attracting force implying a large electric current to be supplied to the coil 14 only exists when it starts attracting the valve body 15 since, afterwards, once the valve body 15 has been attracted, the electromagnetic coil 14 only needs to produce a relatively small force sufficient to maintain the valve member 15 in its attracted state, a large current is requird to be supplied only for a very short duration and, thus, there is no problem of causing a burning damage accident as far as the electromagnetic coil 14 of the injection timing control valve 8 is concerned.

The high pressure fuel injection unit according to the present invention not only enables to provide different amounts of fuel being injected depending on a small lift amount or a larger lift amount of the injection valve body being selected but the timing of operating the lift regulating member can be made offset and advanced with respect to the timing of fuel injection and, therefore, there is no longer a need to employ an electromagnetic coil for the lift solenoid having a very quick start-up characteristic. To the contrary, as the lift regulating member can be triggered to move to its lift regulating position prior to the injection timing the electromagnetic coil 19 having a slow start-up characteristic can be employed as lift regulator for the injection valve body 6. As a result only a small electric current for the lift electromagnetic coil 19 is required and meets the needs of actuating the valve regulating member 20 removing any fear of a burning damage of said coil from occuring.

It should, however, readily be apparent to those skilled in the art that, on the one hand, various stop arrangements for delimiting the movement of the injection valve body 6 to a small degree of injection nozzle opening can be selected and, on the other hand, it is even unnecessary to operate the lift regulating solenoid valve 7 under all running conditions of the engine. For example, in a high speed range of engine each fuel injection cycle requires a sufficiently greater amount of fuel to be injected and, accordingly, normally a maximum stroke of the injection valve body 6 is required leaving the regulating member 20 freely movable and the lift regulator coil 15 currentless. Thus, a lift control of

the injection valve body 6 is performed in response to operational parameters including the running condition of the engine.

Claims

1. High pressure fuel injection unit comprising a housing which defines a fuel injection timing control chamber, accommodating a fuel injection timing control valve therein, and a pressurized fuel storage chamber, leading to a fuel injection nozzle operated through an injection valve body of a fuel injection valve, both chambers being separated by a partitioning wall member which, in turn, defines a back pressure chamber fluidly communicated, on the one hand, to a rear end portion of said injection valve body which is slidably received therein and, on the other hand, to a back pressure relief chamber by means of an orifice passageway which is controlled by said fuel injection timing control valve,
characterized by
a lift regulating member (20) provided to engage a stopper portion (6e) of the injection valve body (6) and, moreover, adapted to selectively assume a predetermined lit regulating position in response to a regulator means (8) being energized in advance of the fuel injection timing.

2. High pressure fuel injection unit as claimed in Claim 1, **characterized in that,**
the fuel injection timing being controlled by an injection timing solenoid actuator (8) adapted to perform a pressure relief control of a back pressure acting upon the rear end face (6h) of the injection valve body (6) to allow a fuel pressure operated movement of the injection valve body (6) for opening or closing the fuel injection nozzle (11a).

3. High pressure fuel injection unit,
characterized by
a lift amount of the injection valve body (6) being controlled by a lift regulating solenoid actuator (7) disposed inside the pressurized fuel storage chamber (5) for disposing the lift regulating member (20) at a predetermined lift regulating position adjusting the lift of the injection valve body (6).

4. High pressure fuel injection unit as claimed in at least one of the preceding Claims 1-3,
characterized in that,
the lift regulating member (20) forms a tubular guide portion (20a) and a disk-shaped atubment portion (20b), said lift regulating member (20) being disposed to surround the injection valve body (6) , wherein said disk-shaped abutment portion (20b) is adapted to abut against a support member (18) of an electromagnetic coil (19) of the lift solenoid actuator (7) and a leading end of the tubular guide portion (20a) is adapted to form an abutment shoulder to engage a radially projecting member (6e) of the injection valve body (6).

5. High pressure fuel injection unit as claimed in at least one of the preceding Claims 1-4,
characterized in that,
the injection timing solenoid actuator (8) comprises a prebiased valve member (15) comprising a valve stem portion (15a) and a disk-shaped abutment portion (15b), the latter having an axially projecting protrusion (15c) adapted to obstruct or open the opposite orifice passageway (3d) which terminates into a back pressure relief chamber (4a) accommodating said disk-shaped abutment portion (15b) of the valve member (15) of the injection timing control actuator (8).

6. High pressure fuel injection unit as claimed in at least one of the preceding Claims 1 to 5,
characterized in that,
said injection timing solenoid actuator (8) comprises an electromagnetic coil (14) made from a thicker winding wire wound in a small number of turns whereas the lift regulating solenoid actuator (7) comprises an electromagnetic coil (19) formed from a thinner winding wire wound in a larger number of turns.

7. High pressure fuel injection unit as claimed in at least one of the preceding Claims 1-6,
characterized in that,
a maximum lift adjusting shim plate (28) is accommodated in the back pressure chamber (3b) in between an abutting wall portion of the back pressure chamber (36) and the rear end face (6h) of the injection valve body (6) to adjusting a maximum lift of same.

8. High pressure fuel injection unit as claimed in Claim 7, **characterized in that,**
the surface of the adjusting shim plate (28) facing to the rear end face (6h) of the valve injection body (6) comprises recessed areas (28b) to increase a fuel pressure acting area of the rear end face (6h) of the injection valve body (6) to improve the response characteristics of the injection valve body (6) for closing the fuel injection nozzle (11a).

9. High pressure fuel injection unit as claimed in at least one of the preceding Claims 1-8,
characterized in that,
a stopper plate (32) made of non-magnetic material is supported on a lower surface of the partitioning wall member (3) facing to an upper surface of the disk-shaped abutment portion (20b) of the lift regulating member (20), wherein the surface of said stopper plate (32) facing the lift regulating member (20) is designed to form recesses (32a) enabling the fuel pressure to act upon the facing upper surface of the disk-shaped abutment portion (20b) of the lift regulating member (20).

10. High pressure fuel injection units as claimed in at least one of the preceding Claims 1-9,

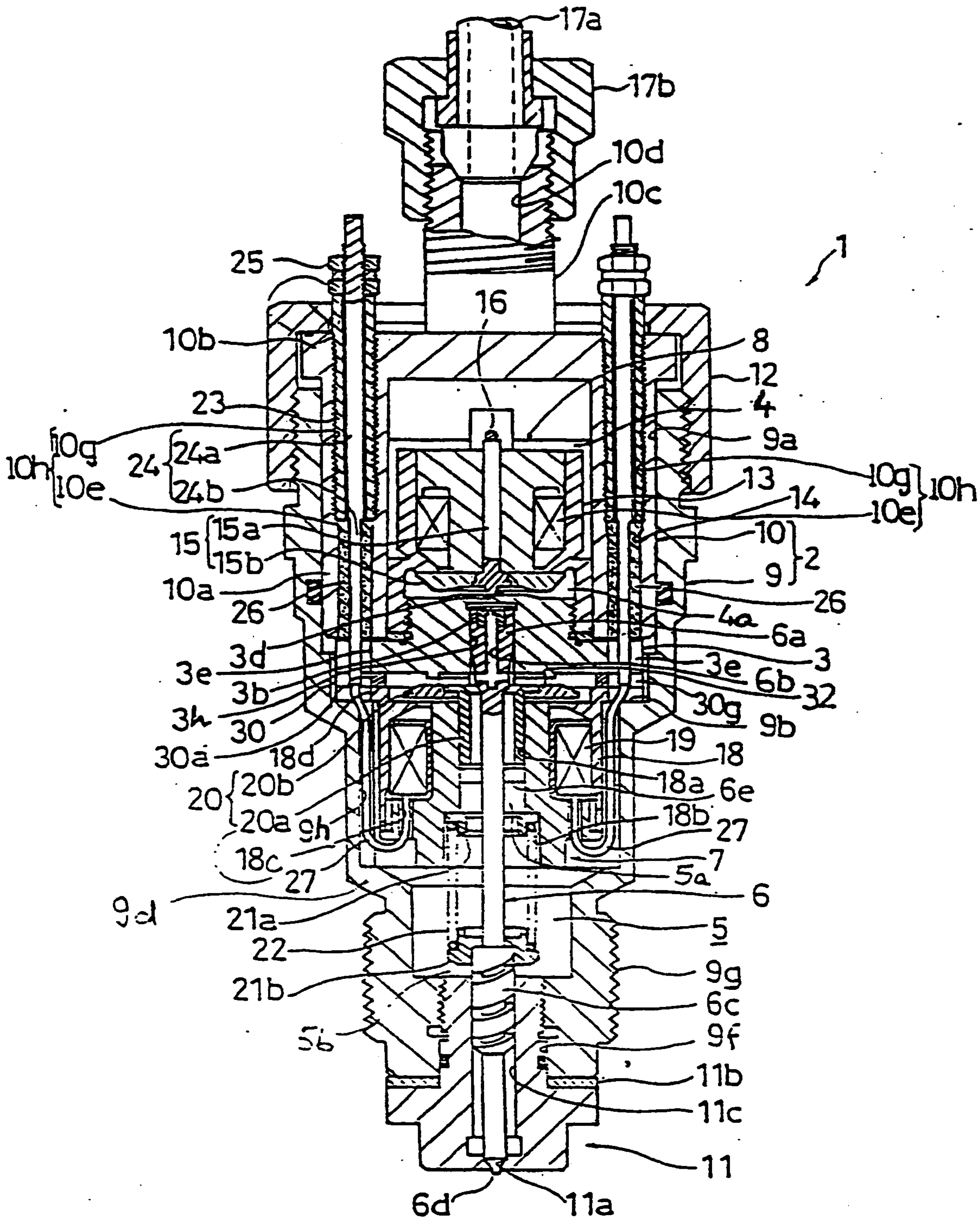
characterized in that,
an air-gap regulator means (18f) is provided at a back side of the disk-shaped abutment portion (20b) of the lift regulating member (20) in order to improve the release characteristics of said member (20b) upon an electromagnetic pull attraction force of the lift solenoid actuator (7) being switched off.

11. High pressure fuel injection unit as claimed in at least one of the preceding Claims 1-10,
characterized in that,
a pair of wiring passages extending axially from an upper top portion of the unit (1) along the injection timing solenoid actuator (8) through a circumferential portion of the partitioning wall member (3) and a receipt structure of the lift regulating solenoid actuator (7) inside the housing (2) to connect to the electromagnetic coil (19) of the lift solenoid actuator (7) from below.

12. Method for controlling a high pressure fuel injection unit having an actuator means for reciprocating an injection valve body of a fuel injection valve and a regulator means for adjusting a lift of the injection valve body, preferably for controlling a high pressure fuel injection unit as claimed in claim 1,
characterized in that,
the timing of energization of the regulator means (7) precedes a timing of energization of the actuator means (8).

13. Method as claimed in claim 12,
characterized in that,
a period of energization of the regulator means (7) precedes a period of energization of the actuator means (8) and a movement of a lift regulating member (20) is completed prior to a valve body (15) of an injection timing control valve (8) being moved.

Fig. 1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12
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24b
13
14
15
15a
15b
10
9
2
10a
26
4a
6a
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3
3e
3b
6b
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3h
30
30g
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20b
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9h
18b
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18c
7
5a
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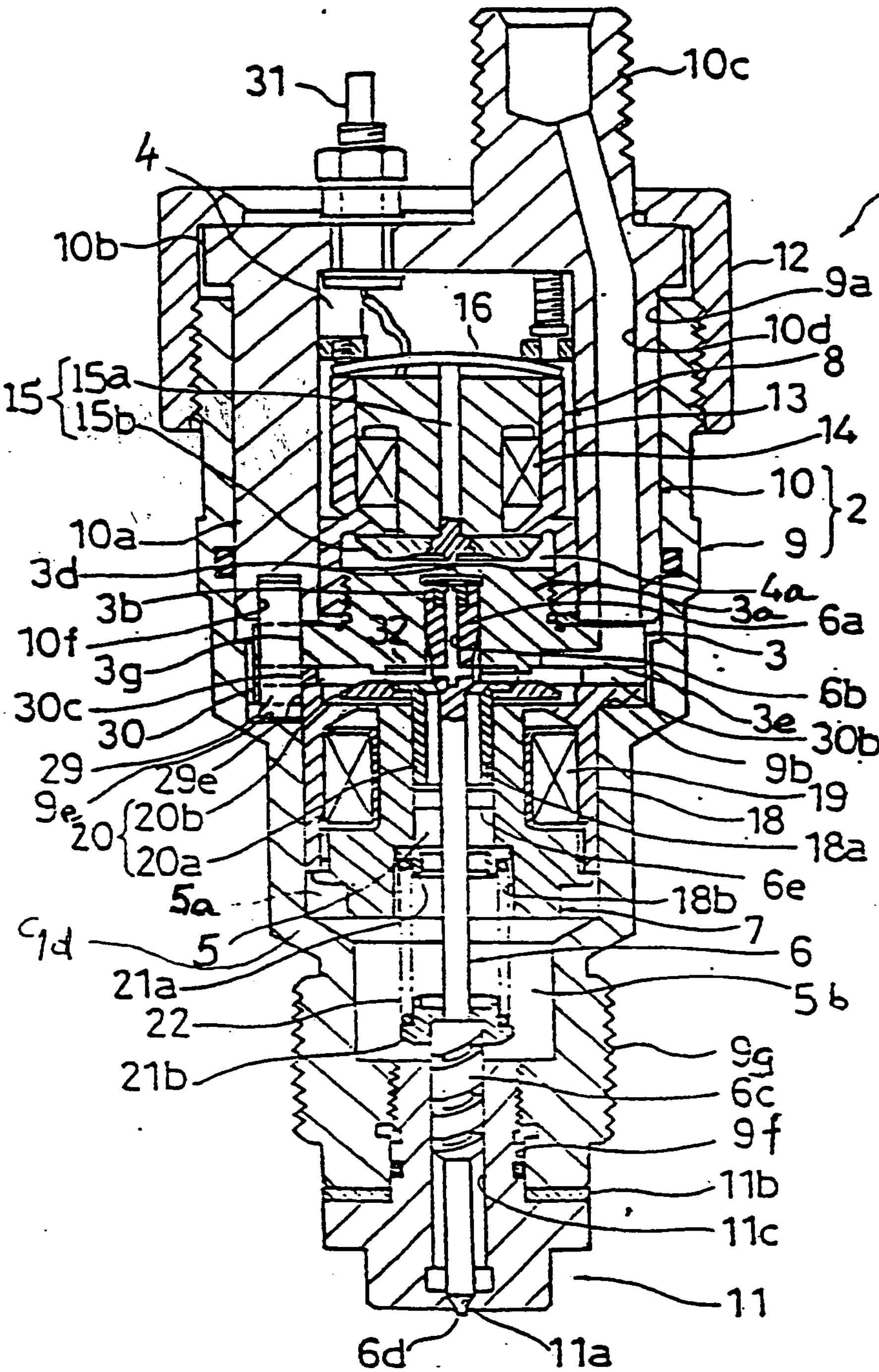
6d
11a

Fig. 2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3d
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3b
3a
6a
10f
32
3
3g
30c
6b
30
3e
30b
29
29e
9b
19
9e
20b
18
20
20a
18a
6e
5a
18b
7
9d
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6c
9f
11b
11c
11
6d
11a

Fig.3

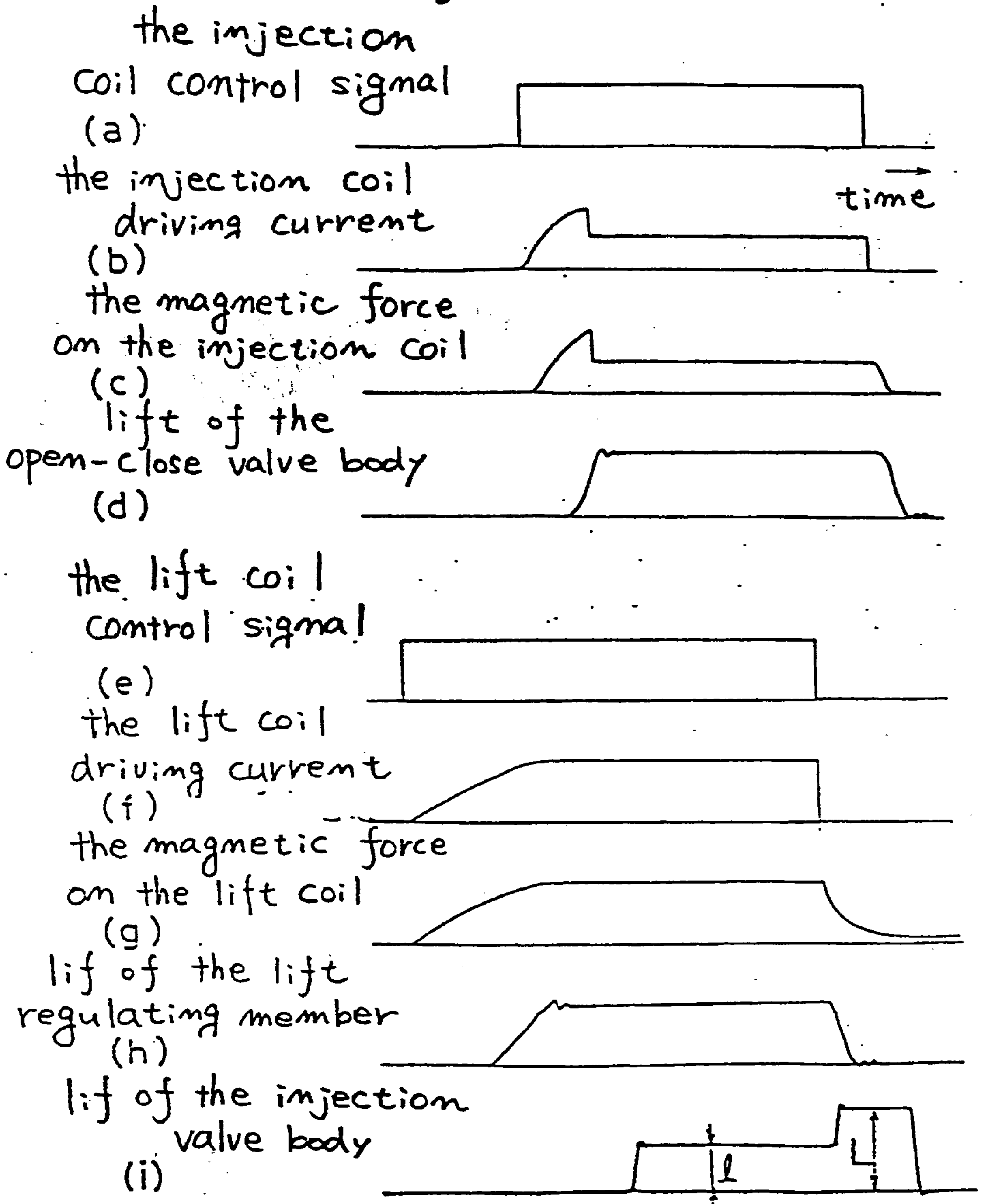

the injection coil control signal
(a)
the injection coil driving current
(b)
time
the magnetic force on the injection coil
(c)
lift of the open-close valve body
(d)
the lift coil control signal
(e)
the lift coil driving current
(f)
the magnetic force on the lift coil
(g)
lif of the lift regulating member
(h)
lif of the injection valve body
(i)
l
L

Fig. 4

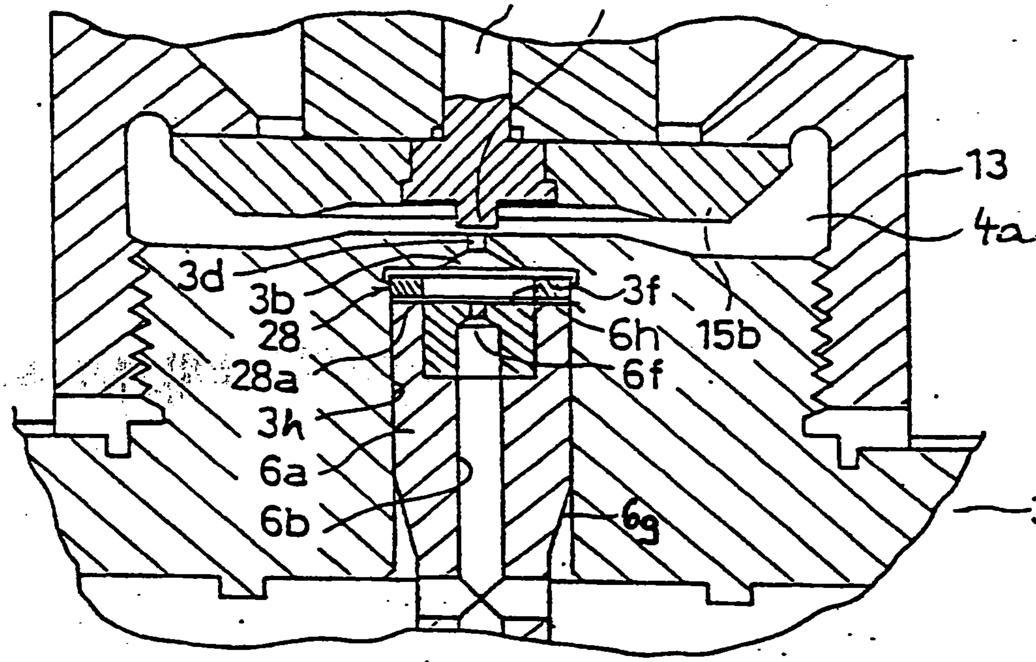
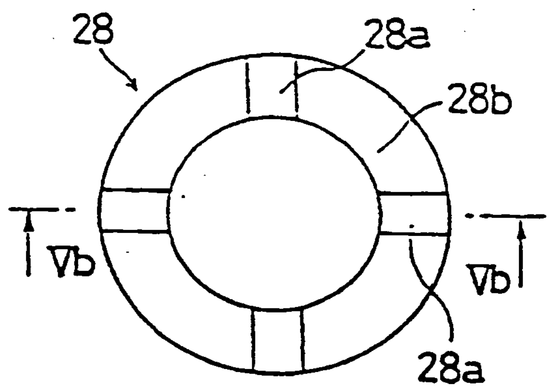

15a
15c
13
4a
3d
3b
3f
28
6h
15b
28a
6f
3h
6a
3
6b
6g

Fig. 5

(a)


28
28a
28b
Vb
Vb
28a

(b)

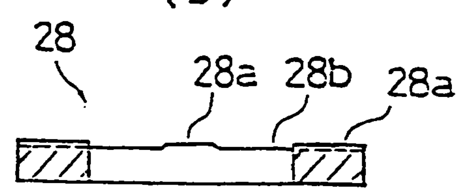

28
28a
28b
28a

Fig. 6

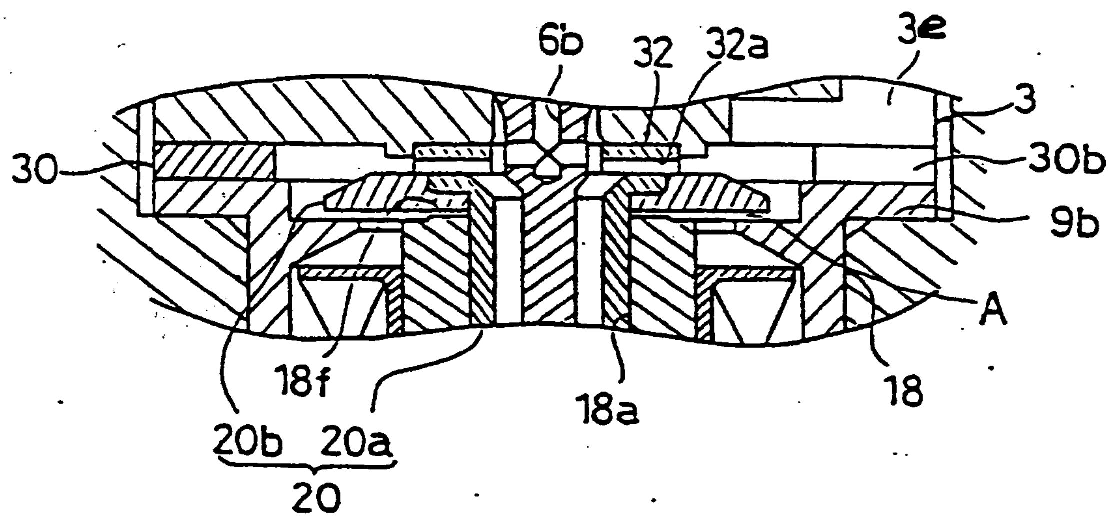
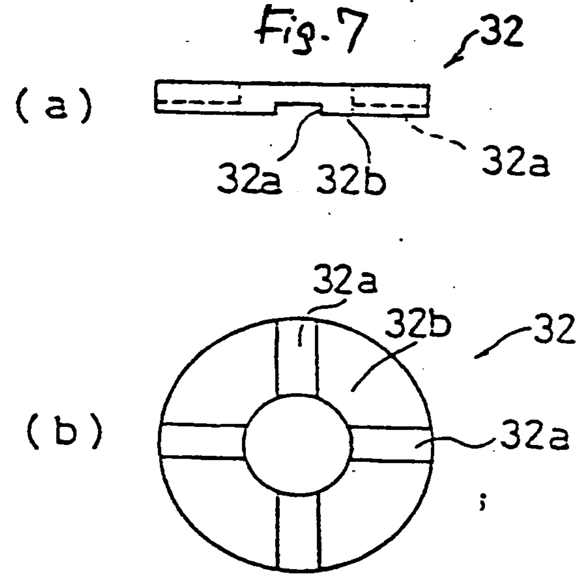

6b
32
32a
3e
3
30
30b
9b
A
18
18a
18f
20b
20a
20

Fig. 7


32
(a)
32a
32b
32a
32a
32b
32
(b)
32a

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 12 1415

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
P,Y	EP-A-0 363 996 (YAMAHA HATSUDOKI KABUSHIKI KAISHA) * the whole document * – – –	1-5,7,12, 13	F 02 M 47/02 F 02 M 61/16
Y	US-A-4 342 443 (R.J. WAKEMAN) * column 7, line 57 - column 8, line 11; figure 2 * – – –	1-5,7,12, 13	
A	EP-A-0 333 096 (YAMAHA MOTOR CO. LTD.) * the whole document * – – – – –	1,2,5	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
F 02 M

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	13 February 91	HAKHVERDI M.

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